

Beyond Chemical - Exotic Energetics/ Propulsion

Dennis M. Bushnell

Chief Scientist

NASA Langley Research Center

The Frontiers of the
Responsibly
Imaginable

“Get what you pay for” and for many decades what we have paid for is improvements to Chemical vice investments in Advanced/ Exotic Concepts/ approaches beyond chemical – WHY we are in the current unsatisfactory situation wrt Climate and Energy

PAVE Propulsion Options

- Biofuels
- Exotic Energetics
- Beamed Energy
- Electric, using either stored or beamed energy
 - Electric motors are lightweight and efficient, THE ISSUE is the long extension cord [AKA weight/ cost Optimization of stored or beamed [ultimately electrical] Energy]

Why Electric Propulsion.....

- Emissions, BUT, H₂O from Fuel Cells a PROBLEM for > 26K ft
- Efficiency, including high altitude
- Cost, reliability, maintenance, safety, flexibility
- Noise
- Distributed Propulsion, synergistic Propulsion & Aero

Just a goodly portion of the Sahara capable of providing [using halophytes, seawater Irrig.] sufficient Biomass to replace ALL of the Fossil Carbon, provide petrochemical feedstock and all the requisite food whilst returning some of the 68% of the fresh water now used for Conventional Agric. to direct human use. Overall – “Solves” land, water, food, energy & warming...

From Bioengineering.....

- Engineered Microbes which utilize CO₂, sunlight and waste water to produce [projected] 20,000 gals of fuel/ acre-year, with Economics competitive with Petroleum at some \$50/bbl. [Petroleum now over \$80/bbl]
- “Joule Biotechnologies” , Nascent Technology, A potential MAJOR transportation fuels breakthrough.

[An] Outlook for H2

- **Green H2 is [eventually] doable**
- **H2 Infrastructure would take too long to put in place [compared to warming/petroleum problem[s] time scales] and is exceedingly expensive**
- **Hydrogen Storage is still nascent, Nano Tech including Casimir Force Engineering could “help”**
- **Fuel Cells cost too much/weigh too much... [However - Recent Parker Aerospace Research looks INTERESTING]**
- **Bottom Line[s].....Biofuel[s] [using existing infrastructures] are/will be the Green transportation fuel of choice.**

Advanced Chemistry

[Sample] HEDM Fuels

- **PolyNitrogen - ISP~ 460**
- **Fluorine/Lithium Hydride - ISP ~ 700 sec.**
- **O₂/Beryllium Hydride - ISP~700 sec.**
- **Solid H₂ - Isp~750 sec.**
- **Cold/ Microporous Silicon**

Beyond Chemical Approaches/Options

- Separation of Propulsive Mass and Energy via Beaming
- Frontier non-chemical Energy Storage/Release

Separation of Propulsive Mass and Energy

- Energy Beaming - MW, Lasers, From Space, Ground or airborne “Platforms”
- Trades for laser vs. microwave – costs, efficiencies, beam diffraction

Beam Diffraction - Energy/ Power Beaming

- Beam Diffraction favors Lasers over Microwaves, laser power and efficiency increasing MUCH, laser costs still higher
- Some intriguing approaches for reducing Beam Diffraction should be investigated/ ideated, potentially huge payoffs
 - Solitons
 - Metamaterials, “Photon Guns”
 - Bessel Beam core
 - X Waves, Bowtie, Mathieu, Airy
 - Energy transfer via Quantum Entanglement/ Teleportation

Reducing Beam Diffraction
obviously also of great interest/
importance for Space Solar Power
[and “Military” applications]

Frontier Energy Storage/ Release Options

- Atomic Fuels, 20X Chem
- SBER – Mechanical, up to 100X Chem Release rates
- LENR – No radiation, up to $E4-E6 \times$ Chem
- Fast Compression – $E3-E4 \times$ Chem
- Isomers – Triggering?, $E5 \times$ Chem
- P-B11 or D-He3 Aneutronic IECF - $E7 \times$ Chem
- Positrons – Storage?, $E9 \times$ Chem
- ZPE - ? [$E108 \times$ Chem?]
- SMES with CNT Magnets
- Metal-Air Batteries
- Nano tube energy storage [H_2 , E-M] in skins/ structures
- The “Exotic Exotics” – Theories relating E-M & Gravity

Atomic Fuels

- Recombination of H atoms releases $\sim 20 \times$ Chemical [Mono-propellant]
- Storage possible either as Metallic Hydrogen or imbedded in solid hydrogen
- Ongoing research for manufacture, storage, release
- Potential Isp to 1200 Sec.

SBER – Structural Bond Energy Release

- P.W. Bridgman [1935], “Explosion of substances subjected to pressure and shear” [e.g. sugar]
- “Excess energy” stored in Chemical bonds due to compressing, stretching and twisting, alter band gaps
- Claims of up to 100 X Chemical release rates, via Nano, $I_{sp} > 700$ Sec., “Cold / much “Faster” Chemistry
- Low TRL, Issues of production, stabilization and release,
- Application to Detonation Wave Propulsion Approaches [“Orion”, Blast Wave Accelerator, ...], Red. Shielding weight for SBER induced Fission via Thermal Neutrons, “Igniter” for Aneutronic Fusion and to “Burn” wider variety of “Fuels”

LENR [Low Energy Nuclear Reactions]

- Originally dubbed “Cold Fusion”, an experimental discovery with replication issues and no acceptable theory
- Now, Almost 2 decades of massive world-wide data collection/experiments indicate is “real”
- Now, a viable Theory [Widom/Larsen]
- Not “Hot Fusion”, is electroweak interactions explicable via the “Standard Model” of Quantum Theory on Surfaces
- Theory being used to increase heat “quality” and practicality, no radioactivity safety issues
- Economics/Utility TBD.....

LENR WLT [J. Zawodny]

- WLT relies on the Weak Nuclear force which:
 - Produces a neutron via electron capture
 - Does not have a Coulomb barrier to overcome
- The theory combines QED, Condensed Matter, Nuclear, and Plasma Physics and also Chemistry
- $p + e^* \Rightarrow n + \bar{\nu}_e$ Inhibited by 0.78MeV
- e^* is a “heavy electron” allowed by QED - requires high electric fields ($\sim 10^{11}$ V/m or 10V/Å)
- High fields result from a breakdown of the Born-Oppenheimer Approximation via a coupling of Surface Plasmon Polaritons to a collective proton resonance in the metal hydride (in the IR).
- The result is an Ultra Low Momentum Neutron which is rapidly absorbed by nearby nuclei.

So you can Visualize.....

- LENR is a volume containing in the current best cases micron sized Ni powder to which H₂ is added along with some energy, how the energy is added [heat, E-M, photons, etc. does not appear to be critical]. Via “weak Interactions [Plasmonics, collective effects, beta decay] nickel is transmuted into copper and heat is produced, with no worrisome radiation, at E3 to E6 times Chemical Energy Density. The device, from Experiment and theory, once up to temperature will run without the energy input for a sizable [80% plus] fraction of the time. These devices have operated for many hours-to-days.

The LENR PROCESS

- Load H₂ onto a metal surface, Plasmons initiate collective effects
- Add some energy, produce high voltage gradients at cracks/ asperities
- Gradients excite electrons, via collective effects [QED] to combine with protons to form an ultra low momentum neutron, never leaves the surface
- Neutron readily absorbed, neutron rich isotope undergoes beta decay , emits heat

NASA Aeronautical LENR Applications

- Overall, enables what we have never had - “Energy Rich” design space[s]
- Fuel fraction becomes negligible, huge impacts upon vehicle gross weights, especially for SST’s which are some 55% fuel fraction
- Use to replace combustors in GTE’s or via Sterling or T-E’s to generate electricity for electric propulsors

Aeronautical Applications Continued

- Huge range increases
- Enables VTOL and PAVE both economical and QUIET
- Enables design for ultra low noise via degrading propulsor performance
- Mitigates sonic boom via focused energy projected far forward to reduce shock strength, “lengthen” vehicle virtually

Aeronautical Applications Continued

- Makes SST's affordable via huge gross weight reductions, reduces sonic boom, enables emission compliance
- “Solves” emissions except for NO_x, which can be mitigated via “design” or obviated if go electric
- Enables huge loiter capability for “sensor craft” [military, climate/ science, law enforcement, HALE Sat substitutes, etc.

Aeronautical Applications Continued

- Reduces both acquisition and operational costs
- Enables envelope-less flight via active flow control, “Bird Like Flight”, ALL-WEATHER
- Provides huge margins to enable superb safety [Armored engine surrounds, triply redundant Faraday caged Electronics, Etc..]

Aeronautical Applications Continued

- Allows direct control of wake vortices to obviate wake vortex hazard
- Super STOL performance via circulation/ flow control to increase runway productivity by a factor of 3
- Overall, For Aero – far lower gross weights, higher speeds, lower noise, greater range, emissions solved, envelope-less/all weather superb ride quality flight, lower costs, greater safety

Aeronautical Applications Continued

- Possibly obviates THE issue with hypervelocity air-breathing, the decreasing value-added from burning H₂ fuel as a function of increasing vehicle kinetic energy
- For the military – EMP on steroids, VTOL obviates air bases/ runways/ carrier decks, enables loitering combined sensor/ weapon devices [instead of getting there in time ARE THERE, always]

WHY has it taken some 22 years?

- Is a non-obvious engineered PROCESS exploiting a backwater of Physics, The Weak Force
- Initial claims of “cold Fusion” Seriously “Poisoned the well”, became the Energetics UFO, 3rd Rail
- Required nearly 2 decades of some excellent experiments AND the Weak Interaction Theory to convince some folks [e.g. LaRC]

We went directly from Chemical to strong force Nuc and in the process bought huge energetics improvements and radiation protection/ safety issues that precluded fission nuc application[s], We leapt over the weak interaction energetics landscape except for radiologics. It is time to back-track.....

Utilization Approaches

- LENR produces Heat, Depending upon design a great deal of heat
- Can utilize the Heat directly as in open propulsion systems etc. or via such as Sterling cycles, Thermoelectrics, Pyroelectrics, T-PV etc. convert the heat into electricity
- Heat produced at energy densities , depending upon design, of E3 to E6 times Chemical, high power density should be possible. All with essentially negligible radiation issues/ problems/ weights and inexpensive fuels/ systems.

Alternative Heat Storage Options

- Fulvalene Diruthenium, Via Molecular Rearrangements
- Zeolite Pellets, Requires water to extract heat, “Infinite” heat storage life, 4X H₂O heat storage [‘Sorptive Heat Storage]

Cold Fast Compression

- Formation of High Energy Density Metastable quantum states in inner shell electrons via sudden compression, $\sim 10\text{-}100$ Mbar
- Decay produces X-rays
- E3 X Chemical
- Low TRL, costs, storage, release forward work

Nuclear Isomers

- Meta-stable nucleus, energy stored as spin or shape changes
- Large number of such, half life varies
- Order of E5 X chemical
- Energy released as high energy Gamma
- Low TRL , VERY serious issues with affordable production, triggering, radiation shielding, Hf178 under study

Positrons

- The “affordable” Anti-matter
- E9 X Chemical, $\sim 100\%$ mass-energy conversion
- Produces .5 MEV Gamma, thermalize to produce heat for propulsion
- Storage is THE ISSUE for Propulsion
Applications, Positronium storage using crossed magnetic and electric fields could, per theory, provide ~ 1 year storage, initial experiments conducted

Aneutronic H-B11 Fusion

Inertial Electrostatic Confinement Fusion

- **Produces Protons, Direct MHD Electricity Generation vice [Neutron] Thermalization**
- **Reduced Radiation Hazard[s]/Weight**
- **High Thrust-to-weight AND High Isp [via reduced shielding, magnetics, High Power Drivers], Large Losses.....**
- **For SSTO, Payload Mass Fraction is ~ 14%, Launch Cost Estimate ~ \$100/lb**

[Some] of the “Flavors” of Fusion

- D-T
- D-He3
- P-B11
- D-D [inertial, proton beams]
- D-D [ULTRA DENSE D, 10 PW Lasers, minimal shielding]

Interstellar Options

- Space warps/ worms
- Quantum Vacuum “Engineering”, ZPE
- Gravity Engineering
- “Surfing Branes”
- Quantum Nonlocality/ Entanglement
- Determining WHAT is actually going on in Physics, Explain Dark Matter/ Energy Etc., Determine best “Theory of Everything” and Apply [e.g. “Dark Matter/ Energy “Harvesting”?]

The Quantum Vacuum ZPF is real!

Dr. Eric W. Davis, Senior Research Physicist, Inst. for Advanced Studies-Austin, 11855 Research Blvd.,
Austin, TX 78759; phone: 512-342-2187; e-mail: ewdavis@earthtech.org

- ◆ Lamb Shift
- ◆ Spontaneous Atomic Emission
- ◆ Low-temperature van der Waals forces
- ◆ Casimir Effect
- ◆ Source of photon shot & fluctuating radiation-pressure noise in lasers
- ◆ Vacuum becomes highly birefringent & dichroic (like nonlinear optical medium) when external magnetic field is applied
- ◆ Astronomically Observed Cosmological Constant (a.k.a. Dark Energy)
→ a cosmological Casimir Energy (via Schwinger-DeWitt Quantum Ether prescription): Energy Density $\approx 10^{-9} \text{ J/m}^3$

ZPE

- Zeroth Order Quantum State
- Energy integrated out to Plank Scales $\sim E 10^8$
X Chem
- Apparent Cosmological Constant indicates FAR less than this level, yet another “Physics Anomaly”
- Several ZPE extraction approaches patented/
under study, a “wild card”

Physics Outlook/Issues

- Quantum and Relativity do not “Merge”
- They do not explain “Dark Energy”[~ 73% of the Universe]
- They do not explain “Dark Matter”[23% of the Universe]
- They do not provide an “understanding” of “Non-Locality”
- Where did the Anti-Matter Go?.....
- 100 plus orders of magnitude difference[s] wrt ZPE between Quantum theory and the operable Cosmological Constant
- Many other “Unsolved Problems”/Anomalies.....

Extant “Explanation” Approaches

[Samples, Additional Degrees of Freedom, Experimental Verification TBD..]

- Time Reversals/Retrocausation”
- Extra [Spatial] Dimensions
 - Many Worlds/Multiverses
 - String/M/Brane Theories [to 11 Dim.]
 - 5 Dim. Larger Universe/ “The Bulk”
- “Larger Constructs”
 - Bohm Quantum Potential
 - Holographic Universe
 - Puthoff ZPAether, Winterberg Planck Aether
- Non-Linear Quantum Theory

Quantum Sitrep.....

- MAGNIFICANT Theory accurate in some cases to 16 to 26 decimal places
- Applications largely based upon “shut up and compute” and FAPP [For all practical purposes]
- No quantum gravity [yet..]
- Quantum Ontology a cottage industry “work in progress”
- “Meaning” of entanglement still “elusive”

Obviously included in these
uncertainties/ arguments etc. is
the nature of TIME.....

What is Sought are “Explanations” for
Dark Matter/Energy and Non-Locality
Etc. which satisfy Occam’s Razor &
Experimentally verified.

Once Found/Determined the
Ensuing/Enabled Technologies should
be Seriously Revolutionary, including
wrt Energy, Stay Tuned.....[ZPE,
Gravity Control, Warps/ Worms,
Teleportation?]

Plank Scale Engineering.....

Beyond Nano is now Quantum Engineering, If/as we sort out the mess Physics is in and intuit/develop valid theories should enable Plank Scale Engineering, as well as MANY other opportunities, depending upon WHAT is Really “going on”.

[Sample] “Different” Physics Theories Associated with Frontier Propulsion

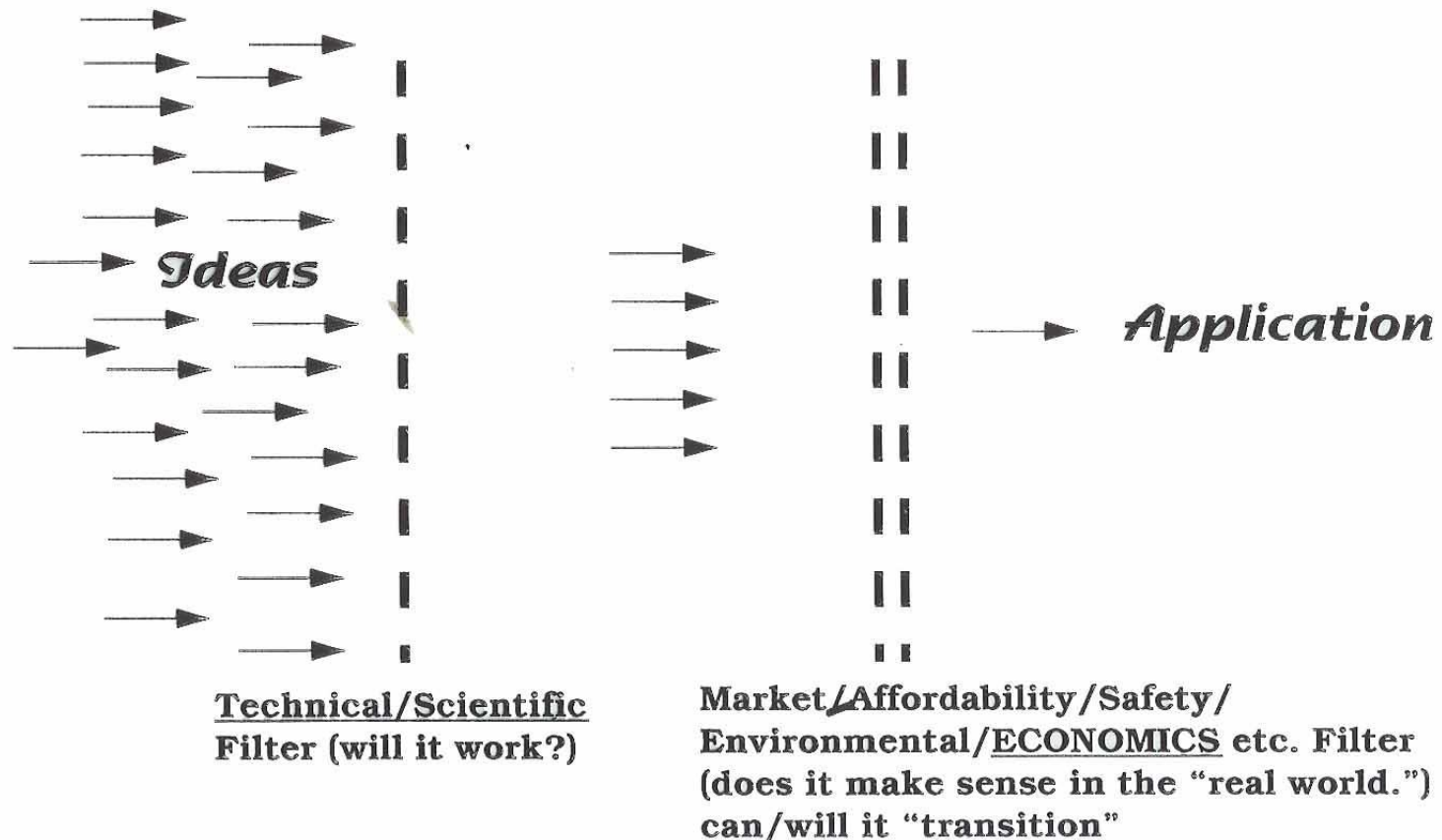
- Puthoff – Engineering the Vacuum Energy
- Heim – Quantized space-time
 - There are several others that rely upon E-M/Gravity interactions
- Machian/ Woodward – Gravity Drive
- Pharis Williams – Compact Aneutronic Reactor

Going Forward.....

Invest in Discovery and Exploratory Research in /for all of the options and triage as learn/ know more, invest in fewer at higher levels, core down/ determine the “best Bets”. At this point our ignorance is such cannot pick winners, need REAL WORK.....

Current Sit-rep for MANY of the
Alternative Energetics/ Propulsion
approaches is Low TRL, View-
Graph/ Power Point Engineering
level

THE (SERIAL) “FILTERS” THROUGH WHICH AN IDEA/APPROACH/CONCEPT MUST PASS BEFORE UTILIZATION



THE “CRUCIBEL” THROUGH WHICH NEW/DIFFERENT (CIVILIAN) DESIGNS HAVE TO PASS

(generic “technology filter” - the “illities”)

ENGINEERING

- Producability/manufacturability
- Maintainability/supportability
- Reliability
- Flyability/airworthiness
- Inspectability
- Performance (aero, structural, propulsive)
- Flexibility (growth, Pax/cargo, variable production rate)
- Repairability
- Operability
- Durability/damage tolerance
- Airport compatibility

THE “CRUCIBEL” THROUGH WHICH NEW/DIFFERENT (CIVILIAN) DESIGNS HAVE TO PASS

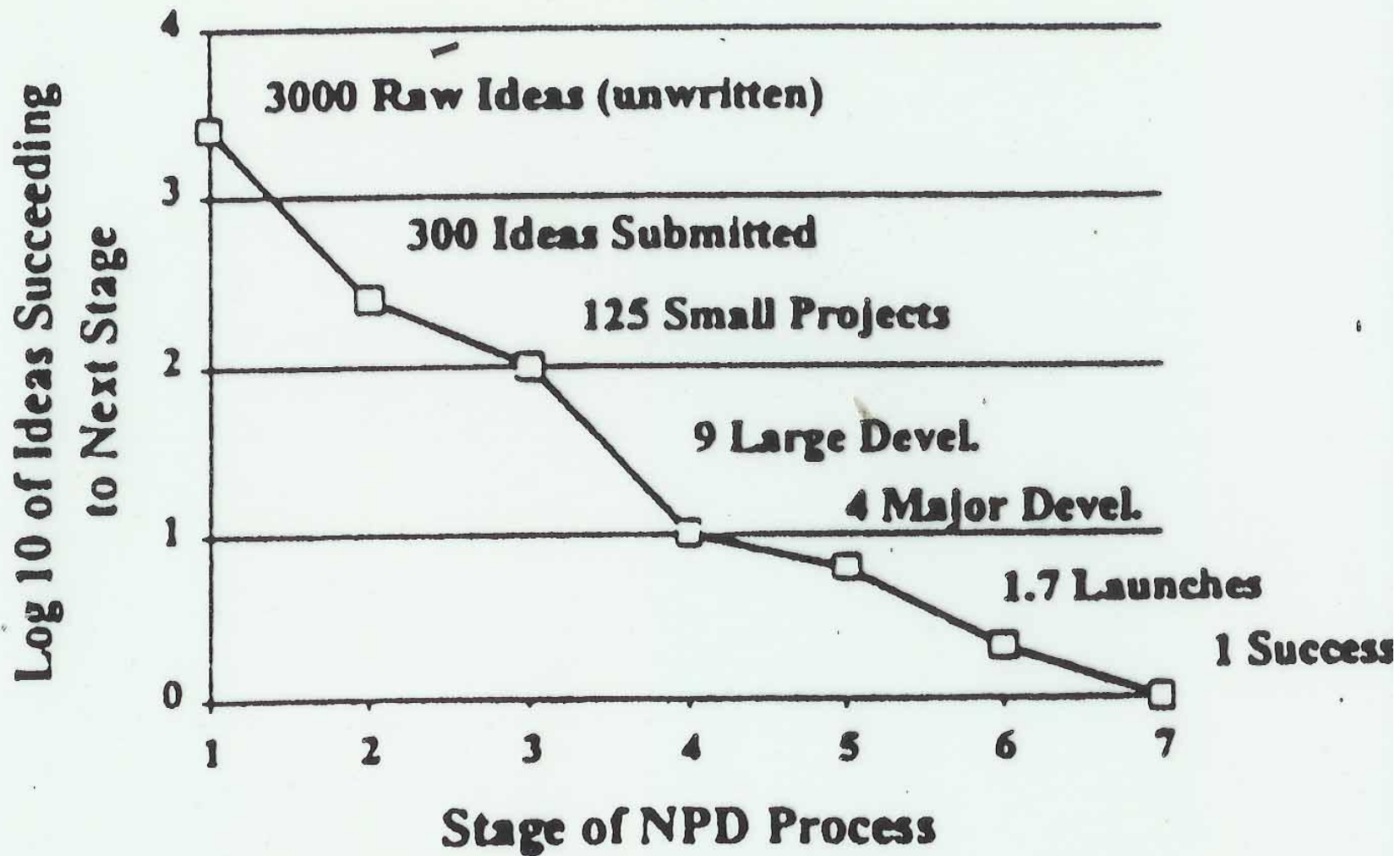
ECONOMIC/BUSINESS

- Profit (airframes/airlines)
- Fuel usage/ “carbon tax”
- Size/weight/part count/material/complexity
- Ancillary/ “side” effects
- Product liability
- Timeliness
- Protectability/ease of duplication/exclusive rights
- Criticality of requirement/novelty
- Regulatory issues
- Risk
- Distribution system
- Availability/productivity
- THE COMPETITION (product, approach)

THE “CRUCIBEL” THROUGH WHICH NEW/DIFFERENT (CIVILIAN) DESIGNS HAVE TO PASS

SAFETY/ENVIRONMENTAL

- “Crashworthiness”
- Vortex hazard
- Weather (icing, microburst)
- Stall/spin
- Fatigue
- Emissions
- Engine and airframe noise



***“Universal” Industrial Success Curve
for Substantially New Products***

Overall.....

A Tremendously varied sandbox, The spectrum of possibilities is astounding, all requiring RESEARCH/ INVESTMENTS, including obviously at the Systems/ Architecture level. The lack of such investments/ Research has condemned us to the shackles and costs of Chemical Propulsion, with folks in some cases willing to “Sell Grandmothers” for a few seconds of Isp when factors of 2 to infinity are on offer..... To state it charitably, this is extremely short-sighted.

“Once upon a time [Pre 2000] in a land not too far away [MSFC] there was a Frontier Propulsion Research Program run by John Cole [Ret.]. This Magnificent program worked many of the areas mentioned herein and supported the pioneering work of Bob Frisbee/JPL [Ret.] and Marc Millis/GRC [Ret.]. NASA has had nothing similar since. The Bobby B./ CTO efforts are attempting to restart such. The other National Advanced Propulsion Efforts are mostly near[er] term. The opportunities are incredibly rich, the demonstrated courage & risk embracing to go there by folks with resources far less so.

“We have met the Enemy & they is us”

For Propulsion vice Energy Source

- High Thrust MHD
 - Field Reversed Configuration [FRC] [Cambier]
Dynamic E-M produces stable plasmoids
 - VASIMR
- Both utilize Magnetic Nozzles, claim ISP above 20,000 seconds at high thrust, VASIMR under active research, FRC has a heritage

“Exotic” Battery Outlook

- Metal-Air batteries - Al, Li, Zn, using ionic fluids?, ~ to hydrocarbon Energy Density [~ vehicle range for same weight], Requires research for rechargeability
- SMES with CNT Magnets – CNT magnets provide the strength, low losses and high field strengths to enable a “ battery” up to some 20X [Hydrocarbon] Chemical
- Nano Tube skins/ structural could be an ultra-capacitor enabling Electrical Storage in the “Entire” vehicle

Comments WRT “Radical Innovation”

“The battle is within. It is a cultural one: between glorifying the past or marching toward the future, between protecting successes or cannibalizing them, between averting risk or embracing it. The battle is for the soul of the of the Industry [and the Future of Humankind]”